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Pain, Severity, and Attentional Capacity Following Acute Musculoskeletal Injury

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PAIN, SEVERITY, AND ATTENTIONAL CAPACITY FOLLOWING ACUTE MUSCULOSKELETAL INJURY

by

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(Under the Direction of Jessica Mutchler)

ABSTRACT

Background: As recreational activities grow in popularity, there is a concurrent rise in musculoskeletal injury. Injury severity is determined through clinical evaluation and defined by a grading scale. Pain is included in the definition of each injury grade, despite the lack of any conclusive evidence relating injury severity and the associated pain. Additionally, previous studies report impairments in cognitive performance due to chronic and acute pain. The aim of this study is to determine the relationship between the perceived pain intensity and the clinically diagnosed severity of an acute musculoskeletal injury, and to determine if attentional capacity is influenced by the presence of acute pain.

Methods: This study was completed in two parts. Part one included sixteen recreationally active participants clinically diagnosed within 24 hours of an acute musculoskeletal injury. Of those, five participated in part two and were tested on attentional capacity. Participants were re-tested on all attentional tests when pain free. Pain intensity was measured with the Visual Analog Scale (VAS). Attention tasks included the Trail Making Test A (TMT-A), Trail Making Test B (TMT-B) and the D-KEFS Color Word Interference Test (CWIT). A Spearman's Rho determined the relationship between grade of injury and pain intensity. The Wilcoxon signed-rank test determined correlations in attentional performance while in acute pain and once pain-free. Both statistical tests used an alpha level of $p > 0.05$ *a priori*.

Results: No significant relationship was found between grade of injury and pain intensity (p = 0.84). Participants had significantly improved performance on the CWIT-1 (p = 0.04) and CWIT-4 (p = 0.04) once pain-free. No significant difference was observed between acute pain and pain-free states for TMT-B (p = 0.07), CWIT-2 (p = 0.46), or CWIT-3 (p = 0.14). Conclusion: Results from this study suggest pain intensity and injury severity are not related, and attentional impairments may be present in patients suffering from acute musculoskeletal injury.

INDEX WORDS: Evaluation, Cognition, Executive function, Neuroscience

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CHAPTER 1

INTRODUCTION

Involvement in recreational activities, such as running, intramural sport, and weightlifting are growing in popularity as the general population seeks to maintain a healthy lifestyle. In 2018, an estimated 218.5 million Americans took part in sports and other activities, 1.6 million more participants than in 2017.[1] As the number of individuals participating in recreational activities continues to rise, there is a corresponding increase in resultant musculoskeletal injury.[2] The pain often associated with musculoskeletal injury is a subjective experience that acts as a signal, alerting a person to the injury and prompting a decrease in activity or need to seek help.[3] Currently, there is no evidence to support a relationship between pain levels experienced and the actual severity of an injury.[4] Further, pain is a known attention-demanding process, and may therefore have an effect on cognition.[5]

Musculoskeletal injury involves damage to bones, muscles, tendons, or ligaments of the body due to physical trauma. A thorough clinical examination determines the severity of injury based on anatomical damage, clinical presentation, functional loss, and mechanism of trauma.[6] One common grading scale describes the severity of a muscular or ligamentous injury as the following: grade 1 is a stretching of the tissue with local pain and point tenderness; grade 2 is a partial tearing of the tissue with moderate pain; and grade 3 is a complete rupture of the tissue with pain present for muscular injuries, but often limited in ligamentous injury due to tearing of the local nerves.[7] Despite the lack of evidence to support pain intensity as a useful predictor for severity of musculoskeletal injury, current level of pain intensity is considered part of the clinical assignment of injury severity.[4,8]

Pain is defined by the International Association for the Study of Pain (IASP) as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage."[9] This definition highlights the lack of congruency between pain and actual tissue damage, as well as the influence of unique sensory and emotional factors on the overall experience.[5] Although pain is an important component to any injury, pain that is non proportional to the assessed tissue damage should not overshadow objective findings in a clinical evaluation. To the researcher's knowledge, there are no studies differentiating between assessed injury severity through clinical evaluation, and the associated perceived pain intensity.

Not only does subjective pain intensity influence the clinician's grading of injury severity, it may also influence patients' ability to receive and process information given to them by the clinician during initial evaluation. Pain processing and cognitive function are two separate processes that share the same neural regions, and therefore, must share the same neural resources.[10] The two regions in the brain that are most commonly stimulated by pain include the anterior cingulate cortex (ACC) and the prefrontal cortex (PFC).[11,12] In addition to pain, the ACC and PFC are engaged with cognitive tasks such as attention.[13,14] Cognition may become disrupted as neural resources are drawn towards the presence of pain, which is known to be interruptive, distracting, and difficult to disengage from.[5,10,15] Evidence from fMRI, PET, and EEG studies further support that pain and cognitive related activity have a modulating effect on one another.[10] Chronic pain patients frequently present with cognitive impairment and decreased performance on neuropsychological tests.[16] A meta-analysis described the pooled results from five studies demonstrating impaired attentional shifting in chronic pain patients as measured with the Stroop Test.[15] Although there is a large body of literature dedicated to chronic pain and

cognitive functioning, few studies have examined the effect that acute musculoskeletal pain and injury may have on cognitive processes.[17,18]

The purpose of this study was to determine the relationship between the perceived pain intensity and the clinically diagnosed severity of an acute musculoskeletal injury. This study further sought to determine if attentional capacity performance is influenced by the presence of acute pain. It was hypothesized that no relationship exists between the pain and severity of an acute musculoskeletal injury. It was further hypothesized that attentional capacity performance would be improved in a pain-free state as compared to while experiencing acute pain.

CHAPTER 2

METHODOLOGY

Experimental Design

Recreationally active participants between the ages of 18-30 years were studied to determine the relationship between injury severity and perceived pain intensity of an acute muscular or ligamentous injury. Additionally, this study sought to determine if attentional capacity performance is influenced by acute musculoskeletal pain. This study was performed in two parts. Part I involved evaluating participants within the first 24 hours of initial injury, or re-exacerbation of a previous injury, and recording their current level of perceived pain intensity.[19] Following the initial evaluation and care of injury but still within the first 24 hours of injury, participants that fit the inclusion and exclusion criteria were asked to participate in Part II and tested on attentional capacity. Participants in Part II were re-tested on the same cognitive tests once they were no longer experiencing pain, between one and three weeks following initial injury. Grade of injury severity, perceived pain intensity rating, and attentional capacity scores from both testing periods were the variables used in this study.

Participants

Participants were recruited from those seeking any type of medical care from a certified athletic trainer (AT) at a single university recreation center in the southeast United States (n = 56). Sixteen individuals (n = 13 male, mean age 19.75 ± 1.36 years; n = 3 female, mean age 19.33 ± 0.58 years) were clinically diagnosed with an acute muscular or ligamentous injury and agreed to participate in Part I of this study. Acute pain was operationally defined as the onset or exacerbation of pain within 24 hours of sufficient severity to necessitate the search for medical care.[19] Five recreationally active participants (n = 5 male, mean age 20 ± 1.23 years) agreed to

participate in Part II. An individual was considered recreationally active if they participated in a minimum of 30 minutes of moderate-intensity aerobic physical activity 5 days a week, or 20 minutes of vigorous-intensity aerobic physical activity 3 days a week.[20] Exclusion criteria for Part II only consisted of the following: suspected fracture, head injury, or altered mental status; injury to the participant's dominant hand; diagnosed concussion within the previous 6 months; color-blind or decreased visual acuity; self-report of an attentional or learning disorder; self-report of depression, anxiety, or any other psychiatric disorder; use of analgesic medication within 24 hours of testing; and those whose primary language was not English.[21-25] Figure 1 provides a visual representation of how eligibility was determined for Parts I and II. Tables 1 and 2 provide descriptive data including ethnicity and year in school for Part I and Part II, respectively.

Table 1. Descriptive Data of Participants for Part I.

		n	%
Ethnicity	White	8	50.0
	Black	4	25.0
	Hispanic	2	12.5
	Asian/Pacific	1	6.3
	No Response	1	6.3
School Year	Freshman	3	18.8
	Sophomore	6	37.5
	Junior	4	25.0
	Senior	2	12.5
	No Response	1	6.3

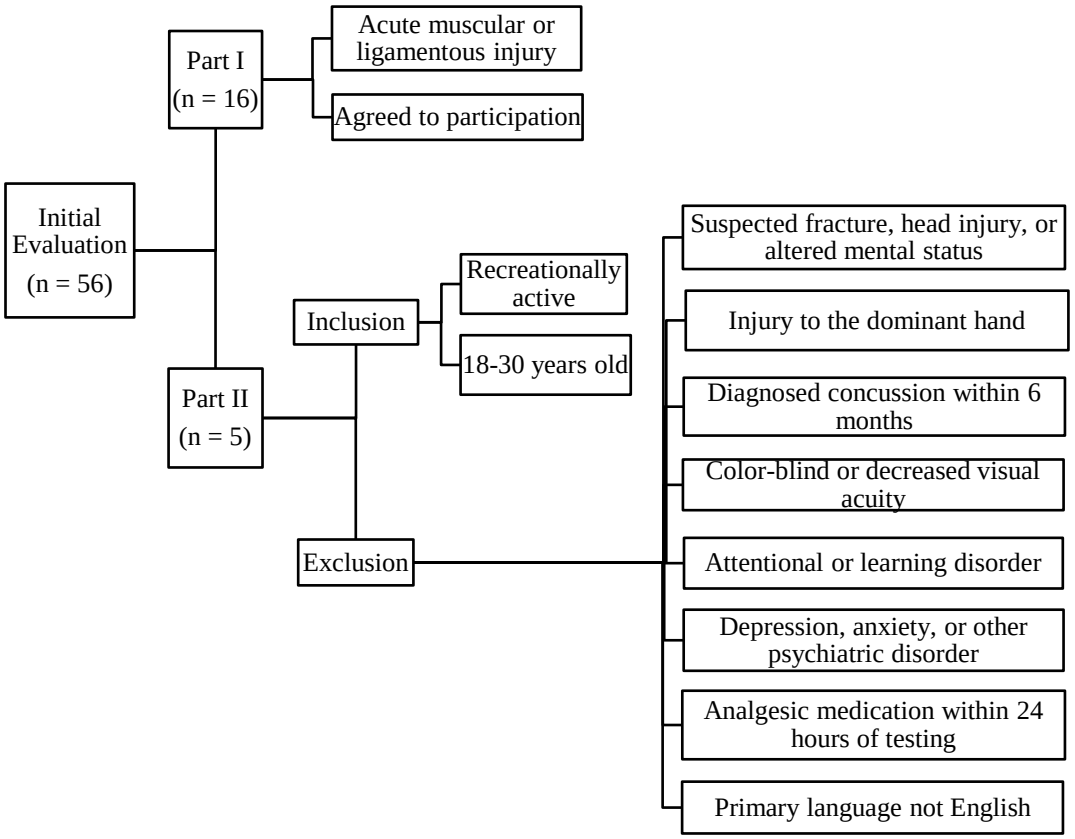
Notes: n = number of participants; % = percentage of participants.

Table 2. Descriptive Data of Participants for Part II.

		n	%
Ethnicity	White	1	20.0
	Black	2	40.0
	Hispanic	1	20.0
	Asian/Pacific	1	20.0
School Year	Sophomore	3	60.0
	Junior	1	20.0
	Senior	1	20.0

Notes: n = number of participants; % = percentage of participants.

Figure 1. Flow Chart Representing Participant Recruitment



Experimental Protocol

The primary investigator for this study was an AT for the university's recreation center. All individuals that sought care following initial injury or exacerbation of a previous injury were evaluated and provided care by the athletic training staff. Initial perceived pain intensity was determined with the Visual Analog Scale (VAS_1). The clinical diagnosis and severity of injury were assigned based on commonly used grading scales and following a thorough clinical evaluation that included relevant history questions, observation, relevant palpations, and special tests. All individuals diagnosed with an acute muscular or ligamentous injury were considered potential participants.

Following completion of the evaluation and care of the injury, only individuals with a diagnosed muscular or ligamentous injury were asked if they would be interested in participating in the study. If interest was expressed, Part I of the study began with the completion of the informed consent and a brief health questionnaire (found in Appendix C). Those injuries determined to be a grade 1 (G1) were considered mild, grade 2 (G2) moderate, and grade 3 (G3) severe. Participants who passed eligibility criteria for Part II were then asked if they would like to continue with Part II of the study. Those participants that agreed were taken to a quiet room to continue data collection where external distractions were limited. Each participant's perceived pain intensity was determined again with the Visual Analog Scale (VAS_2) immediately prior to attentional testing. Attentional capacity was then measured with neuropsychological tests: the Trail-Making Test Part A (TMT-A), Trail-Making Test Part B (TMT-B), and the Color-Word Interference Test (CWIT). The order of test administration was alternated between participants.

Participants were asked to return when pain free, no earlier than one week and no longer than three weeks post injury, to repeat the VAS (VAS_3) and all attention tasks. A follow up

health questionnaire was completed at this time as well (Appendix C). An email was sent to participants one week following the initial testing session to schedule the second testing session. If needed, participants received up to two additional emails as a reminder and for scheduling purposes. Participants who were still experiencing pain at the one week check-in were allowed up to two additional weeks to schedule their followed-up attentional testing.

Instrumentation

VAS. The Visual Analog Scale is a 100 mm continuous line anchored on either end with the cues of "no pain" indicating a score of 0 and "worst possible pain" indicating a score of 100.[26] The score is determined by measuring the distance (mm) between the two endpoints with the following cut points: no pain at 0-4 mm, mild pain at 5-44 mm, moderate pain at 45-74 mm, and severe pain at 75-100 mm.[26] The inherent continuum of an analog scale allows for greater sensitivity and reliability in representing current perceived pain intensity than similar descriptive pain scales.[27]

TMT. The Trail-Making Test includes two parts: TMT-A performed by connecting consecutive numbers from 1-25, and TMT-B performed similarly by connecting alternating numbers and letters in sequence (e.g. 1-A-2-B-3-C and so on).[28] This test is scored by the time to complete each trial in seconds with any errors pointed out immediately and reflected in the final score. The purpose of this test is to measure attention, processing speed, and mental flexibility.[29] Construct validity of the TMT-B supports the test as a complex measure of visual scanning and attention when compared to the paced auditory serial addition test (0.58) and the visual search and attention test (0.50).[30] The mean interrater reliability as measured by intraclass correlation coefficient was high for TMT-A (0.94) and TMT-B (0.90).[31] Standard administration time for

this test is approximately 5-10 minutes. Although only TMT-B was included in the statistical analysis, TMT-A was also administered in accordance with standard administration procedures.

CWIT. The Color-Word Interference Test comes from the Delis-Kaplan Executive Functions Systems (D-KEFS) neuropsychological test battery. This test is designed based off of the Stroop paradigm, one of the most widely used techniques in the measurement of attention and response inhibition.[32] Four conditions are included in this test: (CWIT-1) the naming condition where the participant names the color of 50 different boxes, either red, green, or blue; (CWIT-2) the reading condition where the participant must read 50 different color names – red, green, or blue – printed in black ink; (CWIT-3) the interference condition where the participant must name the ink color of 50 color words where the ink color is never the same as the written word color; (CWIT-4) the switching condition which is the same as CWIT-3 except when any word is in a frame, the word is read instead of naming the color of the ink.[16] The score of this test is determined by time to complete each condition in seconds, resulting in 4 separate scores. Collectively, this test is designed to measure selective attention, cognitive flexibility, working memory, processing speed, and resistance to interference.[29] The internal consistency for this test is considered adequate (0.70 - 0.79) and an ICC correlation revealed adequate test-retest reliability (0.70 - 0.79) with 9-74 days between testing sessions.[29] Standard administration time for this test is approximately 5-10 minutes.

Statistical Analysis

All statistical tests were processed using Statistical Package for the Social Sciences (SPSS) IBM Corp., v.25 (Chicago, IL, USA). Demographic information including ethnicity and year in school was included in a descriptive statistical analysis. The reliable change index (RCI) was used to determine the clinical significance of any change in performance with a 90%

confidence interval to control for neuropsychological testing practice effects.[33] First, the reliable change (RC) was determined using equation 1 where T_1 was the score while in acute pain, T_2 the score while pain-free, and S_{DIFF} the SD of the difference scores. Equation 2 was used to then determine the RCI, or absolute value of the difference score required for a change in score to be considered reliable.

$$RC = \frac{T_1 - T_2}{S_{DIFF}} \quad (1)$$

$$RCI = S_{DIFF} \times 1.645 \quad (2)$$

A Spearman's Rho correlation was used to determine the relationship between the diagnosed severity of an injury and the corresponding perceived pain intensity. The Wilcoxon signed-rank test was used to compare the perceived pain intensity and attentional capacity scores while in pain (T1) and once pain-free (T2). Comparisons investigated the differences between VAS_2 and VAS_3 to confirm a change in pain between sessions, and the differences between the TMT-B at each time point and all four conditions of the CWIT at each time point to determine if changes existed in attentional capacity between sessions. The alpha level to determine statistical significance for both the Spearman's Rho and the Wilcoxon signed-rank test was set *a priori* at $p < 0.05$. Effect sizes were calculated using Cohen's d where a small effect is defined as $d = 0.2$, a medium effect is $d = 0.5$, and a large effect when $d = 0.8$.

CHAPTER 3

RESULTS

Upon initial evaluation of all 16 participants included in Part I of this study, 25% (n = 4) presented with “mild” pain, 62.5% (n = 10) presented with “moderate” pain, and 12.5% (n = 2) presented with “severe” pain as recorded by the VAS_1. Of all 16 participants, 68.8% (n = 11) were clinically diagnosed with a G1 injury, 25% (n = 4) with a G2 injury, and 6.3% (n = 1) with a G3 injury. A Spearman’s rank-order correlation was run to determine the relationship between all 16 participants’ grade of injury and VAS_1. The results indicated that no relationship was demonstrated ($r_s = 0.054$, $p = 0.841$).

Of the 5 participants that were included in Part II of this study, 80% (n = 4) were clinically diagnosed with a G1 injury and 20% (n = 1) with a G2 injury. None of the participants were clinically diagnosed with a G3 injury. Perceived pain as determined by the VAS_2 was rated as follows: 20% (n = 1) as “mild” pain, 60% (n = 3) as “moderate” pain and 20% (n = 1) as “severe” pain.

The Wilcoxon signed-rank test indicated a significant change between the acute pain state (T1) and the pain-free state (T2) on the VAS, the CWIT-1, and the CWIT-4 as indicated in Table 3. A decrease in mean time to complete while pain-free as compared to while in acute pain was seen in the CWIT-1 (T1: 26.40 secs ± 3.29; T2: 23.60 secs ± 2.79) and the CWIT-4 (T1: 54.80 secs ± 8.23; T2: 48.20 secs ± 6.1). Each of these results additionally had a large effect size as determined by Cohen’s *d*. No statistically significant differences were observed in the remainder of the attentional tests when comparing the acute pain and pain-free sessions. Means and standard deviations (SD) for all variables in Part II are shown in Table 3.

Table 3. Pain Perception and Attentional Capacity Scores for Each Session					
Pair	**Time**	**Mean (s)**	**SD**	***p***	**Cohen's *d***
VAS	T1	48.60	25.12	0.043*	2.72
	T2	0.20	0.45		
TMT-B	T1	45.80	12.38	0.068	0.55
	T2	40.00	8.28		
CWIT-1	T1	26.40	3.29	0.042*	0.92
	T2	23.60	2.79		
CWIT-2	T1	20.40	3.65	0.461	0.15
	T2	19.80	4.15		
CWIT-3	T1	40.40	7.57	0.141	0.20
	T2	38.80	8.11		
CWIT-4	T1	54.80	8.23	0.043*	0.91
	T2	48.20	6.01		

Notes: VAS = Visual Analog Scale; TMT-B = Trail Making Test B; CWIT-1 = Naming condition; CWIT-2 = Reading condition; CWIT-3 = Inhibition condition; CWIT-4 = Inhibition/Switching condition; T1 = acute pain; T2 = pain-free.
* represents a significant difference between time points ($p < 0.05$).

The reliable change index (RCI) with a 90% CI determined that one of five participants had a reliable change for the CWIT-1, and CWIT-2 scores. Two of the five participants had a reliable change for the CWIT-3, and four of five had a reliable change for the CWIT-4. The difference scores and RCI for each CWIT condition are detailed in Table 4. For TMT-B, the RCI was 35.60 seconds with a 90% CI. None of the participants had a difference in score great enough to be considered a reliable change (DIFF = 7, 3, 15, 4, and 0 respectively).

Table 4. RCI of the CWIT with a 90% Confidence Interval					
Participant	RCI	CWIT-1 DIFF	CWIT-2 DIFF	CWIT-3 DIFF	CWIT-4 DIFF
P6_C	2.98	2	0	3*	10*
P8_C	3.49	3	3	3	6*
P9_C	2.98	1	-2	0	12*
P10_C	3.49	3	-1	-2	4*
P13_C	2.98	5*	3*	4*	1

Notes: RCI = Reliable Change Index; CWIT-1 = naming condition; CWIT-2 = reading condition; CWIT-3 = inhibition condition; CWIT-4 = inhibition/switching condition; DIFF = difference in scores (T1 – T2).
* represents a score greater than the RCI, indicating a reliable change.

CHAPTER 4

DISCUSSION

The purpose of this study was to determine the relationship between the perceived pain intensity and the clinically diagnosed severity of an acute musculoskeletal injury. It further sought to determine if attentional capacity performance is influenced by the presence of acute pain. It was hypothesized that there is no relationship between the pain and severity of an acute musculoskeletal injury, and that attentional capacity performance would improve once pain-free as compared to an acute pain state.

Consistent with the hypothesis, no relationship was observed between the diagnosed severity of injury and the associated perceived pain intensity. Mixed results were seen when comparing performance on attentional capacity tests completed while experiencing acute pain to once pain-free. Scores on the CWIT-1 and CWIT-4, when pain-free, significantly improved from those recorded while participants were experiencing acute pain. Previous studies have reported a decrease in cognitive performance related to chronic and acute pain, although none focused solely on how attention was impacted by acute pain in the recreationally active population.[15-18] To the researcher's knowledge, no previous studies have differentiated between injury severity and the associated perceived pain intensity reported during the clinical evaluation of an acute musculoskeletal injury.

Injury Severity and Perceived Pain

No relationship was observed between the diagnosed severity of an acute musculoskeletal injury and the associated pain experienced. Although individual differences in the perception of pain intensity have previously been recognized, no studies have examined the relationship between pain and diagnosed injury severity.[34] In an attempt to confirm the validity of patients'

subjective report of pain as recorded by the VAS, one study revealed that almost all patients diagnosed with injury also reported ailments, but many patients that reported ailments did not get a diagnosis.[4] This would suggest that the subjective report of pain had a high sensitivity and low specificity when determining the presence of actual tissue damage, but no description of the severity of injury was mentioned in that study. The results of the present study then contribute to the limited literature in demonstrating the lack of congruency between perceived pain and assessed tissue damage.

The wide variance in pain perception between individuals may further be explained using the neuromatrix theory of pain. This theory suggests that the pain experience is determined by the combination of sensory, motivational, and cognitive information.[3] Each of these factors contributes to one overarching network, or neuromatrix, that is genetically determined and continuously modified by sensory experiences.[3,35] Components such as present context, past history, and future implications play a large role in the pain experienced with an acute injury.[36] It is suggested that pain is the product of a widely distributed neural network in the brain rather than the result of injury, inflammation, or any type of pathology.[3] The lack of relationship observed in this study between perceived pain intensity and diagnosed injury severity, which was used to describe the extent of assessed tissue damage, lends support to this theory.

Pain and Attention

Mixed results were observed regarding the effect of pain perception on attentional capacity. Improvements were seen in time to complete the CWIT-1 and CWIT-4 when participants were pain-free as compared to while in acute pain. These differences were further supported by large effect sizes of 0.92 and 0.91 respectively. The CWIT-1, or the color naming condition, provides a baseline for basic naming skills.[29] Low scores on this test generally indicate a word-finding

impairment, a developmental disability, limited exposure to the English language, or some other neurostructoral factor that may affect mental processing speed.[29] The CWIT-4, or inhibition/switching task, requires adequate naming speed, reading speed, verbal inhibition, and cognitive flexibility.[29] As there was no significant change in the CWIT-2, or reading condition, it was not suspected that acute pain had a detrimental effect on reading abilities or speed. Further, no significant change existed in the CWIT-3, or inhibition task, indicating that acute musculoskeletal pain did not have an effect on verbal inhibition. There was an attempt to control for developmental disabilities and limited exposure to the English language. These results then suggest that acute pain may have an adverse effect on word-finding, naming speed, and cognitive flexibility, but not on reading abilities or verbal inhibition.

Previous studies using the stroop effect have observed performance reductions of inhibition in chronic pain patients.[37] In fibromyalgia patients, a close association was also seen between pain severity and the magnitude of performance decline on cognitive tests.[37] Compared to the current study, it appears that chronic and acute pain may affect different aspects of attentional capacity, as the current participants did not demonstrate a significant decline in inhibition. This may be due to a variance in pain severity or the duration of the pain experience. It is also possible that the level of pain experienced by the current participants was not high enough to have an effect on inhibition tasks.

When examining differences between each time point, the RCI reveals individual participants that reached what would be considered a reliable change in attentional task performance. One participant was determined to have a reliable change on CWIT-2, and two participants were considered to have a reliable change on CWIT-3. These results indicate that despite the lack of significance in group changes, individual participants did show improvements once pain-free.

This is a clinically relevant finding that should be further explored in future research with a larger sample size. On the CWIT-4, four of the participants had a reliable improvement in their scores once pain-free, further supporting that complex attention may be affected by acute pain.

Unlike previous studies, no statistically significant change was seen in the TMT-B, a measure of attention, speed, and mental flexibility. Although not statistically significant (p = 0.068), the mean improvement of 5.8 seconds on the TMT-B while pain-free may be clinically relevant, and was supported by a medium effect size of 0.55. A decline in performance on this task has been reported in patients with both chronic and acute pain.[15,18] Chronic pain patients were slower in completing the TMT-B as compared to healthy controls, indicating slow to moderate impairments in set shifting.[15] Slower completion was also seen in patients suffering acute pain as compared to their own pain-free state, indicating a similar effect between acute and chronic pain on set shifting.[18] The difference in findings between the current study and previous literature may be due to the small sample size reported in this study or a practice effect of the test metric. As the results of this study were near significance with a medium effect size, a larger sample size may better reveal impairments in this attentional task. A better method to control for the practice effects of the test metric may also have an impact on these outcomes.

Scores from both the CWIT and the TMT-B were compared to normative data. Scaled scores for the CWIT were determined based on age and time to complete each condition with a highest possible score of 19.[38] Participants' mean scaled scores while pain free were average for CWIT-1 and CWIT-2, and just above average for CWIT-3 and CWIT-4 (CWIT-1: 11.8 ± 1.30; CWIT-2: 11.2 ± 2.49; CWIT-3: 12.8 ± 1.92; CWIT-4: 12.0 ± 1.22). While in acute pain, participants' mean scaled scores were average for CWIT-1, CWIT-2, and CWIT-4 and just above average for CWIT-3 (CWIT-1: 10.8 ± 1.64; CWIT-2: 11.0 ± 2.35; CWIT-3: 12.6 ± 1.82; CWIT-4: 10.4 ±

2.07). For the TMT-B, participants in the current study completed the task in less time when pain-free (40.00 ± 8.28 secs), and while in acute pain (45.80 ± 12.38 secs) than the available population norms (48.97 ± 12.69 secs).[39] Therefore, practice effects may have a substantial influence over the results of this study.

There were several assumptions and limitations within this study. It was assumed that all participants gave their full effort when completing each attentional test. As the exclusion criteria were determined through self-report, it was also assumed that participants were honest in reporting their current amount of physical activity, relevant previous medical history, and did not purposely exaggerate their current levels of pain. Limitations were present in both the design and execution of this study.

In determining the severity of each musculoskeletal injury, a clinical evaluation was performed by a single athletic trainer, and no imaging was used to confirm the severity of each diagnosis. Although imaging tools are useful to confirm the magnitude and exact location of injury, and in the prediction of recovery time and risk of recurrence, routine imaging is not justified nor often performed upon initial clinical evaluation in traditional athletic training practice.[40,41] Evidence suggests that a clinical examination is just as accurate as an MRI in predicting time to return to competition following a muscular strain.[8,40] As it is not common practice to request imaging following minor musculoskeletal injuries, it was decided that the use of a clinical evaluation would be more applicable to current practices. Furthermore, referrals to a physician for follow-up evaluations are primarily based on the grading of the injury upon initial evaluation, which was more relevant to our research questions.

No control was used to limit the effects of caffeine on attentional performance. As caffeine is a stimulant that reduces mental fatigue, it has been suggested to modulate the

inhibitory control of attention when consumed in doses above 200-250 mg.[42,43] Due to methodological differences such as habitual consumption of participants and timing of dosages, it is unclear to what extent caffeine affects cognitive performance.[43] Those who habitually consume high levels of caffeine may also be negatively affected by the lack of caffeine consumption prior to performance on an attentional task due to withdrawal effects.[44] There is some evidence to suggest that sustained attention is also improved when tested immediately following exercise.[42] The previous study reporting decreased performance on the TMT-B while in acute pain administered cognitive tasks within 72 hours following initial injury, whereas this study administered all tests within 24 hours of initial injury.[18] It is possible that the beneficial immediate effects of exercise on attention overshadowed some adverse effects of pain.

Within any type of neuropsychological testing, practice effects remain a major limitation. Within this study, not all of the participants reached the minimum improvement necessary to be considered a reliable change. Therefore practice effects were likely to have played a role within the final results and influence the conclusions that can be made from this study. Another limitation within this study involves the sample size. With so few participants included, the results of this study should be considered exploratory only, and further research with a larger sample size would be necessary to reach proper power. Finally, all attentional testing was completed in an office located next to a busy recreational gym where not all noise and potential distractors could be completely controlled. This study was delimited to a recreationally active population between the ages of 18 – 30 years at a single university in southeast Georgia. As such, the results of this study may not be generalizable to a more sedentary population or to those under the age of 18 or over the age of 30.

CHAPTER 5

CONCLUSION

The results of this study indicated that no relationship existed between the diagnosed severity of an acute musculoskeletal injury and the associated perceived pain intensity. Further, pain following an acute musculoskeletal injury in a recreationally active population may have adverse effects on attentional components such as word-finding, naming speed, and cognitive flexibility, but not on reading abilities or verbal inhibition. The results of this study are preliminary, and a larger sample size would be required to further explore the relationships between diagnosed injury severity, the associated perceived pain intensity, and the resultant effect on attentional capacity.

Clinical implications suggest that the inclusion of pain descriptors in the definition of grading scales may introduce a bias to a clinician's initial evaluation of an acute musculoskeletal injury. Accurate grading scales are vital in determining appropriate prognostic and therapeutic directions. An initial clinical evaluation should prioritize objective findings such as the presence or absence of functional and structural integrity rather than the reported pain intensity in determining the clinical diagnosis. Clinicians should also be aware of the potential for impaired attention following an acute musculoskeletal injury. Impairments in cognitive flexibility may alter a patient's ability to focus on vital information conveyed to them, rather than the attention-demanding pain they are experiencing. When providing important information to patients who are experiencing acute pain, these results support the use of a written format rather than oral delivery alone.

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APPENDIX A

Revised Research Questions and Hypotheses

- **RQ_1:** Is there a relationship between the perceived pain intensity and the diagnosed injury severity of an acute musculoskeletal injury?
- **H_1:** No relationship exists between the perceived pain intensity and the diagnosed injury severity of an acute musculoskeletal injury.

- **RQ_2:** Is attentional capacity performance influenced by the presence of acute pain as compared to a pain-free state?
- **H_2:** An improvement in attentional capacity performance will exist when a participant is pain-free as compared to while experiencing acute pain.

Inclusion Criteria

- Participants that are 18-30 years of age and recreationally active
- Presentation of acute pain due to muscular or ligamentous injury

Exclusion Criteria

- Suspected fracture, head injury, or altered mental status
- Injury to the dominant hand
- Diagnosed concussion within the last 6 months
- Decreased visual acuity or reported color-blindness
- Reported diagnosis of attentional or learning disorder
- Reported diagnosis of depression, anxiety, or other psychiatric disorder
- Analgesic medication used within 24 hours of testing
- First language is not English

Limitations

- Participant's failure to return for repeat testing
- Lack of imaging to confirm severity of injury
- Clinical diagnosis of injury severity determined by a single novice athletic trainer

Delimitations

- A young adult population that is recreationally active at a single university

Assumptions

- Participant honesty regarding level of physical activity, self-report of pain, and previous medical history.
- Participant effort during all cognitive testing

Operational Definitions

- **Recreationally Active:** participates in at least 30 minutes of moderate-intensity aerobic physical activity on 5 days a week or at least 20 minutes of vigorous-intensity aerobic physical activity on 3 days a week.[20]
- **Acute Pain:** within 24 hours of initial injury or re-exacerbation of prior injury.[19]

APPENDIX B

LITERATURE REVIEW

Background

Physical activity within the general population is frequently promoted to maintain health and reduce the risk of obesity. It has recently been estimated that over 300 million Americans took part in sports and other fitness activities in 2018, which is 1.6 million more participants than in 2017.[1] As the number of people participating in physical activities continues to increase, there is a simultaneous increase in the number of athletic injuries.[2] This higher incidence of injury and the associated pain experience has become an important public health concern as it often results in high costs (i.e., medical bills, days of work lost), fear of participation, or a negative view of sports and exercise.[2,45]

Many of the negative aspects of athletic injury are due to the pain experienced. Pain is considered acute when it is the expected physiological response following injury; if it then persists beyond a normal healing time, it is considered chronic.[11,15] There is evidence to suggest that chronic pain may alter cognitive function.[15,37,46,47] Studies have documented chronic pain patients' report of cognitive difficulties and impaired performance on neuropsychological tests.[16] Management of chronic pain has begun to incorporate attention and distraction tasks as emerging evidence suggests a modulating effect between pain and attention.[48] Currently, very few studies have considered the effect of acute pain on cognitive function.[17,18]

Executive functions are high-level cognitive processes that are necessary for flexible behavior, including adaptation to new or changing situations.[49] Attention may be considered as one domain within executive functioning as it is a means by which specific information is selected for further processing in the brain.[29] The concept of attention includes both the ability to

concentrate on one task and to ignore distractors. Pain is a known attention-demanding process suggested to interfere with cognitive tasks, especially those involving attention.[5,10]

The following is a review of the current literature on the interaction between pain and executive function, specifically within the attentional domain. The main topics include: a general overview of the classification of musculoskeletal injury; the definition and process of pain; definitions for cognition and executive functioning; the interaction between pain and cognitive functions; assessments of executive function and pain intensity.

Musculoskeletal Injury

The musculoskeletal system involves all bones, muscles, tendons, and ligaments of the body. Injury occurs when these tissues sustain damage due to some physical trauma.[50] Injuries to the musculoskeletal system specifically may include fractures, dislocations, sprains, or strains. A thorough clinical examination is necessary in determining what structures are involved and how severe the damage may be. This examination then forms the base for a clinical diagnosis.[6] Within a typical evaluation, the following five steps are used to ensure that no potentially serious injuries are missed: palpation of bony structures, palpation of ligamentous structures, assessment of range of motion, testing of musculature, and special tests.[51] This clinical assessment is also useful to obtain an accurate prognosis of injury.[41]

Many common musculoskeletal injuries, such as sprains and strains, are assigned a grade of severity based on the findings of the clinical examination. These grading systems are beneficial to clinicians and athletes as they provide both prognostic and therapeutic direction.[52] Currently, there are no standardized grading systems for sprains or strains; however, clinicians commonly assign the grade of severity based on anatomical damage, clinical presentation,

functional loss, mechanism of trauma, stability, proposed treatment needed, or any combination of these factors.[53] The American Medical Association Standard Nomenclature System is frequently used in the grading of a ligamentous sprain, and is based on anatomic damage.[54] Within this system, Grade 1 indicates a stretched ligament, Grade 2 a partial tearing of the ligament, and Grade 3 describes a completely torn ligament.[54] Based on clinical presentation only, Jackson, Ashley, and Powell devised a classification system using the terms mild, moderate and severe.[55] A mild sprain is characterized by minimal or no swelling, minimal functional loss, point tenderness, and pain with reproduction of the mechanism of injury; a moderate sprain includes moderate functional loss, localized swelling, and point tenderness; and finally a severe sprain includes diffuse tenderness and swelling, and an unwillingness to support weight.[55]

For the classification of a muscle strain, imaging such as MRI or ultrasonography may be used to provide information on the size, severity, and precise location of injury.[41] This use of imaging may be advocated for to further understand the extent of damage, which is useful in determining prognostic factors such as recovery time.[56] Studies have found a strong correlation between a clinical examination and MRI results to predict actual time to return to competition.[41] Routine imaging in clinical practice is often not justified due to the acceptable accuracy of a clinical examination.[40,41] Regardless of clinical or radiological diagnosis, the most widely used muscle injury grading systems are based on three grades of injury determined to be minor (Grade 1), moderate (Grade 2), or complete (Grade 3).[52,57] Grade 1 is considered a strain with few muscle fibers involved, complaints of swelling and discomfort, and minimal strength and function impairment. Grade 2 is a partial tear with some continuity among the muscle fibers at the injury site, impairments in strength and athletic activities involving high-speed and high

resistance, and obvious lack in muscle function such as ability to contract. Grade 3 is considered a complete tear with a loss of all muscle function.[56]

Pain

Definition and Process

The International Association for the Study of Pain (IASP) defines pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage." [9] Three important qualities of the pain experience are highlighted in this definition: it has unique sensory and perceptual characteristics, it is an unpleasant emotional experience, and no absolute relationship exists between pain experience and tissue damage.[5] Therefore it is not surprising that this complex process, involving both sensory and emotional components, will vary greatly between people and within a single individual depending on the context of the pain and the individual's current mental state.[12]

Pain is classified as either chronic or acute depending on its duration. According to the IASP, pain is considered chronic when it persists beyond the normal or expected healing time, or is typically assigned at three months.[15] The ultimate indication of chronic pain is structural, functional, or chemical changes to the brain and central nervous system.[15] Acute pain is the expected physiological response to adverse chemical, thermal, or mechanical stimuli which may be associated with any surgery, trauma, or illness.[11] The immediate experience of acute pain is strongly influenced by the attitudes, beliefs, and personalities of the patient.[11]

Pain is a multidimensional experience produced by multiple influences.[35] Any threat to tissue integrity results in the firing of nociceptive neurons, discharging at a rate that is proportionate to the intensity of the stimulus.[11] The inflammatory response is initiated by tissue

destruction, and sustained by immune cells and multiple mediators such as monoamines, cytokines, prostanoids, and peptides.[11] These mediators work to sensitize functional nociceptors or activate any that are dormant.[11] Through the interaction of these inflammatory mediators and receptors, the nociceptive input is integrated and modulated into the peripheral nervous system.[11] C and a-δ fibers send the nociceptive information to the dorsal horn located within the spinal cord, where it is then relayed on ascending pathways to the thalamic, limbic, and cortical structures responsible for a reaction.[11]

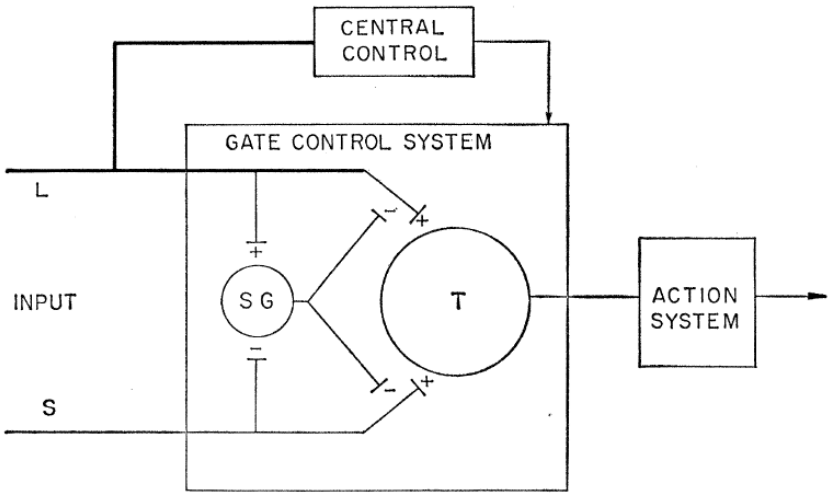
Within the brain, certain areas including the primary (S1) and secondary (S2) somatosensory cortices, anterior cingulate cortex (ACC), insula, prefrontal cortex (PFC), thalamus, and cerebellum are activated by noxious stimuli.[12] These brain pathways are connected to different aspects of the pain experience: S1 and S2 encode the sensory features such as location and duration of pain; the ACC and insula are components of the limbic system that encode the emotional and motivational aspects of pain.[12] Pain may also occur without any noxious stimulation, as seen in amputee patients with phantom limb pain.[58]

Theories of Pain

In 1965, Ronald Melzack and Patrick Wall developed the gate control theory.[59] Within this theory, it is suggested that stimulation of an individual's skin elicits nerve impulses that are then conducted through three spinal cord systems (Figure 1). These systems include the substantia gelatinosa in the dorsal horn, the afferent dorsal-column fibers, and the first central transmission (T) cells also located in the dorsal horn.[59] The substantia gelatinosa is the gate that modulates the afferent pattern of the nerve impulses. The afferent dorsal-column fibers, or the fibers that project towards the brain, are the central control trigger. As such, they have the power

to activate selective brain processes and influence how the nerve impulses are modulated at the gate, or substantia gelatinosa. The T cells activate the mechanisms responsible for the response to and perception of these nerve impulses. The interaction between all three systems aids in the determination of pain phenomena.[59]

Figure 2. Schematic Diagram of Melzack and Wall's Gate Control Theory[59]

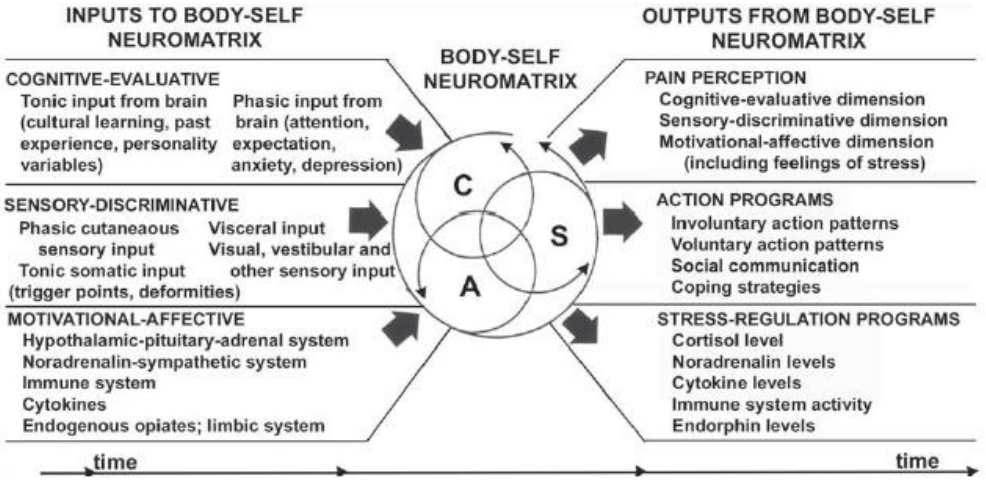


Note: Large-diameter (L) and small-diameter (S) fibers project to the substantia gelatinosa (SG) which modulates afferent patterns before they influence the T cells (T). The T cells activate the action system responsible for response and perception. The central control trigger influences the modulating properties of the gate control system. Data from Melzack and Wall, 1965[59]

This theory is crucial as it places the central nervous system as a key component to the pain process, forcing the medical and biological communities to accept the brain as an active system in processing sensory inputs.[35] It describes a process that involves the brain rather than just the peripheral nervous system. It further describes the dorsal horns as a site that dynamic processes such as inhibition, excitation, and modulation can occur, rather than just a passive system.[35] However, this theory does not completely capture what determines an individual's

perception of pain, especially when no noxious stimulus is present. For that, Melzack proposed the concept of the neuromatrix.

Figure 3. Neuromatrix Theory of Pain[3]



Note: The body-self neuromatrix is shaped by cognitive (C), sensory (S), and affective (A) neuromodules. The resultant output patterns influence the neurosignature, shaping the pain experience and behavioral response. Data from Melzack, 2001.[3]

The neuromatrix theory of pain describes pain as a multidimensional experience that is determined by the individual's unique neurosignature (Figure 2).[3] The experience of any sensory event is derived from the combination of afferent information from the peripheral system and cognitive information such as present context, past history, and future implications.[36] These factors all influence one overarching network, labeled the neuromatrix, which is genetically determined then altered by sensory inputs and experiences.[3,35] As the brain continuously processes and synthesizes incoming information through the neuromatrix, a characteristic pattern develops creating an individual's unique neurosignature. This neurosignature is continuously flowing and adapting based on the incoming information, providing a continually adapting self-

awareness.[3] This theory places genetics and the neural-hormonal mechanisms associated with stress as equally important as those associated with sensory transmission.[35] With so many factors involved, it becomes evident that pain is produced by a wide neural network in the brain rather than the direct result of sensory input from injury, inflammation, or some other pathology.[3]

Pain Perception

For centuries, vast differences in pain perception have been recognized.[34] Using the Fear-Avoidance Model, the perception of pain may be broken down into two basic components: the sensory component and the emotional reaction component.[60] The emotional component may further be divided into pain experience, pain behavior, and the physiological response to painful stimuli.[60] Each of these components is designed to work together, and any imbalance may result in an exaggerated pain perception.[60]

Biological differences are also responsible for some of the variations in pain perception. For example, sex has been suggested to impact ratings of pain perception. In one study women are reported as recording higher mean subjective pain ratings than their male counterparts.[61] In the comparison of young male and female subjects with an experimental noxious heat stimuli applied, females rated the heat stimuli as more intense than the males did, regardless of the gender of the experimenter.[62,63] Positron emission tomography (PET) scans show a significantly greater activation of the PFC in females as compared to males, suggesting that this difference in pain perception may be due to sensory factors rather than the result of an attitude or emotional response.[62,63]

In addition to emotional and biological differences, cognition also has an important impact on the perception of pain.[12] Perception involves both active processing of sensations and

filtering of sensations away from the conscious mind. In order to achieve these processes, attentional factors must play a large role.[64] Within the perception of pain, attention must be turned towards the pain to evaluate its intensity and qualities.[10] Further, pain demands attention due to the biological importance of nociception.[10] As pain is able to actively consume attention, it naturally has easy access to consciousness.[16]

Cognition and Executive Functions

Within the realm of neuropsychology, cognition involves the information processing of behavior.[64] It is considered a functional property of individuals as it cannot be directly observed, but must rather be inferred from behavior.[64] The functional components of cognition involve what and how much knowledge, skill, and intellect a person may have.[65] Executive functions are a type of high-level cognitive processing that facilitates new behaviors and works to optimize one's approach to any new or unfamiliar circumstances. It is through these functions that people are able to behave flexibly and adapt to new or changing situations.[49] As such, they are responsible for many of the factors that enable a person to lead an independent and purposeful life.[49] Executive functions can further be described as an interaction between the goal-directed activity of the brain and attention-demanding peripheral input.[15] These processes are thought to be supported in the frontal lobes of the brain.[49] Although there are several subclasses of executive functions, three distinguishable cognitive components are often highlighted, including information updating and monitoring ('Updating'), inhibition of prepotent responses ('Inhibition'), and mental set shifting ('Shifting').[66]

Updating is closely linked to working memory. It requires both monitoring and coding incoming information based on the relevance of the current task, and then revising the

information already stored in working memory; any old or irrelevant information is replaced with new or more relevant information.[66] Working memory, and therefore updating, is often associated with the prefrontal cortex.[66] Inhibition involves the deliberate suppression of dominant, automatic, or prepotent responses whenever necessary.[66] It involves blocking a habitual response in favor of a less familiar one.[66] Shifting involves switching back and forth between multiple tasks, operations, or mental sets, and is thought to involve the frontal lobes of the brain.[66,67] This process is closely related to attentional control as it includes subsequently disengaging from the old or irrelevant task and actively engaging in the new, more relevant task.[66]

Attention may be thought of as the gateway of information flow to the brain.[29] Models of attention frequently divide it into component processes including: alertness/arousal, focused attention, selective attention, divided attention, and sustained attention.[29] It should be noted that many of these tasks may overlap and no consensus has been reached on the exact meaning of each of these terms.[29] Different attention-demanding tasks have been found to engage the same group of brain regions, including the PFC, the ACC, and the posterior parietal.[13,14] The brain has inherent limitations on the amount of information that can be processed at a given time. The ability to select specific information to further process, or directing attention towards specific information, is necessary to function effectively.[29] Attention is considered a common capacity or resource that must be divided between tasks. When the demands of tasks exceed the resource availability, thought and behavior may slow, stop, or become flawed.[5]

Pain and Cognition

Evidence from fMRI, PET, and EEG studies suggest that pain and cognitive activity interact in the brain with a modulating effect on one another.[10] Pain is an attention-demanding process, requiring enhanced neural resources in brain structures that overlap with executive functions.[5,15] The PFC plays a key role in both the neuromatrix of pain and executive functioning.[37] Therefore, it is not surprising that cognitive performance may be disrupted by the presence of pain. It is currently unknown if the cognitive load or intensity of pain alters the level of interaction.[10] Studies have suggested that activity in afferent pain pathways are also altered by attentional state, both positive and negative emotions, empathy, and a placebo effect.[12]

The current available research on pain and cognition generally focuses on chronic pain patients. Within the clinical community, it is widely accepted that chronic pain is associated with a decline in cognitive performance.[15,16,47,68] In one outpatient multidisciplinary chronic pain program, 62% of the patients reported moderate to severe difficulties in at least 1 out of 5 cognitive domains.[68] These cognitive impairments may then lead to difficulties in social situations and everyday functions, even in chronic pain patients with no history of neurological disorders.[16] These deficits are associated with both subjective cognitive impairments and objective neuropsychological test performance.[16,47] A comparison across five studies with chronic pain patients specifically suggested impaired set shifting with a medium effect size.[15]

Several studies concerning pain and cognition focused on fibromyalgia syndrome, a condition involving chronic, widespread pain in the muscles, tendons, and joints. Reduced performance on tasks of memory and attention, both selective and sustained, has been observed in affected patients.[37] A close association between the severity of pain and magnitude of performance decline supports the idea that it is the interference effect of pain that is altering

cognitive function.[37] The severity of pain had a larger impact on attention, arithmetic abilities, and implicit memory than other modifying factors such as depression and anxiety, suggesting that those factors play a subordinate role.[37]

Very little research is currently available evaluating the effect of acute pain on cognitive functioning.[17,18] One study compared the performance of a healthy control group, a group of athletes with a concussion, and a group of athletes with an acute musculoskeletal injury on a computerized neuropsychological test battery.[17] Interestingly, the musculoskeletal injury group performed significantly worse than the control, but not significantly different then the concussion group.[17] In another study, recreationally active participants that were administered a neuropsychological test battery, both in a pain free state and following an acute musculoskeletal injury, performed worse on measures of immediate recall and complex attention when following acute injury.[18] These results bring to light the potential for cognitive deficits in any patient suffering acute pain due to a musculoskeletal injury.

Assessments

Trail Making Test (TMT)

The Trail Making Test is a pen-and-paper neuropsychological assessment designed to measure attention, processing speed, and mental flexibility.[29] It is one of the five most commonly used measures by neuropsychologists, and ranks as the top instrument to measure attention.[69,70] This test is administered in two parts, Trail Making Test A (TMT-A) and Trail Making Test B (TMT-B). In TMT-A, a line is drawn connecting consecutive numbers from 1-25. In TMT-B, a similar line is drawn connecting alternating numbers and letters (i.e. 1-A-2-B and so on). The

score is based on the time to complete each trail; any errors are immediately pointed out for correction and reflected in the final score.[28]

This test is designed for use with adults aged 15-89 years, and only takes 5-10 minutes for administration. The test-retest reliability for this assessment was found to be adequate for both TMT-A (0.7) and TMT-B (0.8).[71] This test is both efficient and sensitive in reliably differentiating between individuals with brain impairment and those without.[28] A majority of the studies examining set shifting in chronic pain patients utilize a version of the TMT, resulting in lower scores for both TMT-A and TMT-B as compared to healthy controls, with more errors on TMT-B.[15] The clinical interpretations drawn from this test appear to be valid when compared to a set-switching task, confirming that this test may be confidently used to assess executive function.[28]

A normative set of data was developed for the TMT consisting of 680 individuals, ages 18-89 years. The sample contains both male and female participants and an education level ranging from 5-25 years. Trails A and B were both administered following standard guidelines, with the instruction to complete each part as quickly and accurately as possible.[39] Table 1 displays a sample from the normative data set for ages 18-34 years old.

Table 5. Statistical properties of the TMT normative data set stratified by age, education, gender, and Trails A and B (s).

Age Groups	Mean ± SD	Median	Min-Max
Ages 18-24 (n=155)			
Age	20.17 ± 1.48	20.00	18-24
Education	12.92 ± 1.01	13.00	10-15
Gender	1.59 ± 0.49		
Trail A (s)	22.93 ± 6.87	21.70	12-57
Trail B (s)	48.97 ± 12.69	46.00	29-95

Ages 25-34 (n=33)			
Age	29.42 ± 2.87	30.00	25-34
Education	14.18 ± 1.61	14.00	11-18
Gender	1.58 ± 0.50		
Trail A (s)	24.40 ± 8.71	23.00	10-45
Trail B (s)	50.68 ± 12.36	50.00	29-78

Color-Word Interference Test (CWIT)

The Delis-Kaplan Executive Function System (D-KEFS) is a collection of 9 tasks designed to assess the different components of executive functioning.[29] This system was designed to allow for flexible use so that the included tests could be used together or individually.[29] This system was standardized with a nationally represented, stratified sample including 1,750 participants: children, adolescents, and adults aged 8-89 years. Age, sex, race/ethnicity, years of education, and geographic region were all accounted for based on the 2000 U.S. Census.[38] The Color-Word Interference Test (CWIT) is one assessment included within the system that is designed to evaluate attentional processing and psychomotor speed.[16,29]

The CWIT involves 4 conditions: color naming, word reading, inhibition, and inhibition/shifting respectively. Color naming involves naming the color of 50 different colored spots (red, green, or blue). Word reading involves reading color words (red, green, or blue) printed in black ink. Inhibition involves naming the color of ink that color words are printed in where the color of ink never matches the color word. Inhibition/switching adheres to the same rule as the inhibition task, except for any word that has a frame around it which must be read instead of the color of ink named. The participant is instructed to complete each of these tasks as quickly as possible without making mistakes.

The CWIT was designed based off of the Stroop Effect, one of the oldest and most commonly used methods of evaluating attention and response inhibition.[32] Originally developed

by J. Ridley Stroop in 1935, the stroop effect is observed when an individual must inhibit the natural response of reading a color word while actively processing the color of ink that the word is printed in.[72] It is a measure of cognitive control and suppressing a habitual response in favor of a less familiar one.[29] This effect is included in several neuropsychological testing batteries due to its reliable and robust assessment of attentional processing.[73]

Although the D-KEFS test battery has received some criticism for few reliability values reaching values greater than 0.8, this variability should be expected due to the broad spectrum of cognitive processes being measured.[74] Reaching a greater psychometric stability is limited due to the demands of measuring executive functions. The CWIT specifically has shown adequate test-retest reliability (0.70-0.79) and a high internal consistency (0.62-0.86).[29,74] Moderate correlations were reported between the D-KEFS test battery and the Wisconsin Card Sorting Test suggesting the validity of this system.[74] In the measurement of individual executive functions, evidence suggests this test battery to be the most thorough and precise.[74]

Visual Analog Scale (VAS)

The visual analog scale (VAS) is a 100 mm line that the patient places a mark on to measure how much pain they are currently experiencing, or their current pain intensity. The two ends of the line represent two extremes, labelled to correspond to the absolute minimum and maximum amount of pain possible, with an infinite number of points between the extremes.[75,76] The score is obtained by measuring from 0 mm to the point marked by the patient.[77] This tool is considered to be the best method available for recording perceived pain or pain relief.[78]

The continuum of an analog scale results in a greater sensitivity than other measurements that rely on descriptive terms.[76,78-80] The visual analog scale is considered to be the most

sensitive method of measuring perceived pain intensity.[75] The reliability of this scale is well established, with ratings as high as r = 0.97 with between-session experimental pain trials, and is rated as the preferred tool for participants.[76,77,79,81]

Summary

Musculoskeletal injuries such as sprains and strains are often categorized as mild, moderate, or severe. The level of pain associated with injury is often included in the determination of the severity of injury, despite the wide variations seen in the perception of pain. A threat to tissue integrity will fire nociceptive neurons initiating the pain process; however, pain is a multidimensional experience that is affected by sensory, cognitive, and even emotional factors according to the neuromatrix theory of pain.[3,11]

While cognition determines what and how much knowledge, skill, and intellect a person may have, it is the higher-level cognitive processes of executive functioning that allow flexible behavior and the ability to adapt with new and changing circumstances.[49,64] One domain within executive functions includes attention, a resource that is divided between multiple tasks.[5] Due to the brain's inherent limitations of the resources available, the ability to direct attention towards specific information for further processing is crucial to function effectively.[29] Thought and behavior will become slow, flawed, or stopped when the resource limit has been met.[5]

Both pain and cognition activate the ACC and PFC, requiring the neural resources to be shared between both processes.[13,14] Evidence from fMRI, PET, and EEG studies further suggests that an interaction and modulation occurs when both processes are present.[10] The current literature supports decreased cognitive function in chronic pain patients and in patients subjected to laboratory-induced pain such as a cold pressor task.[12,15,82,83] There is limited support for a

decrease in cognitive function with acute musculoskeletal pain as well.[17,18] More studies should be conducted to further explore any modulating effects between acute clinical pain and cognitive tasks. The VAS is a useful method in determining the current level of pain intensity experienced by the patient.[26] Instruments such as the TMT and CWIT are well established methods of measuring cognitive functions, such as attention, and demonstrate good validity and adequate reliability.[28,29,71]

APPENDIX C: Questionnaires and Assessments

INFORMED CONSENT

GEORGIA SOUTHERN UNIVERSITY

WATERS COLLEGE OF HEALTH PROFESSIONS

DEPARTMENT OF HEALTH SCIENCES AND KINESIOLOGY

Informed Consent
Pain and Acute Musculoskeletal Injury Severity as Predictors of Attentional Capacity

1. My name is Rebekah Roessler and I am a second year graduate student in the M.S. in Kinesiology – Athletic Training Emphasis program. I am also working as a graduate assistant athletic trainer for Injury Prevention and Care at Campus Recreation and Intramurals. I am conducting this research for my graduate thesis project.

2. The purpose of this research is to determine if injury severity and/or perceived pain intensity are predictors of attentional capacity following an acute musculoskeletal injury. Further, this study seeks to determine if the level of perceived pain intensity predicts the severity of acute musculoskeletal injury, and to determine if a change in perceived pain intensity predicts a change in attentional capacity.

3. Participation in this research will include completion of a pre-participation health questionnaire, the recording of your initial visual analog scale (VAS) to determine current pain intensity, documentation of your injury severity as assessed through the clinical examination, an additional VAS after the clinical assessment, and two 10-minute long neuropsychological tests: the Trail Making Test Parts A and B, and the Color-Word Interference Test. One week following initial testing you will be emailed to set up one follow up testing time which must be completed no later than three weeks following initial testing. Two additional follow up emails may be sent if necessary. Follow up testing will include completion of a follow-up health questionnaire, the VAS, the Trail Making Test Parts A and B, and the Color-Word Interference Test. If you do not meet the inclusion/exclusion criteria of this study, you will not be required to complete the attentional testing and follow up attentional testing components. Your pain severity and injury severity information will be de-identified and included in the final data analysis.

4. The associated risks with participation in this study are no greater than risk associated with daily life experiences. Slight mental discomfort may be experienced due to the neuropsychological tests used, although this is not anticipated. If mental discomfort does occur, testing may be stopped at any time without consequence. You understand that medical care is available in the event of mental discomfort resulting from this research. Should medical care be required, you may contact your primary care physician, or if you are a student who has paid your Health Fee, you may schedule an appointment at Georgia Southern University Student Health Services via your Online Student Health Portal. You may also contact the Georgia Southern University On-Campus Counseling Center at 912-478-5541.

5. You will likely receive no direct benefit for participation in this study. However, you will be provided with your results, once calculated, upon request. The results of this study have the potential to improve clinical assessments and take home care instructions provided by health care professionals following acute musculoskeletal injury.

6. Initial data collection is expected to take approximately 45 minutes, which includes the time taken for the clinical examination. The follow-up session is expected to take ≤30 minutes.

7. All information gathered within this study will remain confidential and secure in a locked file cabinet in a locked office in a secure building. The primary investigator will have sole access to any identifiable information. All identifiers will be removed prior to any statistical analysis or reporting of results. Data will be stored on a password protected computer in the custody of Dr. Jessica Mutchler and destroyed 3 years after the conclusion of the research.

8. De-identified or coded data from this study may be placed in a publically available repository for study validation and further research. You will not be identified by name in the data set or any reports using information obtained from this study, and your confidentiality as a participant in this study will remain secure. Subsequent uses of records and data will be subject to standard data use policies which protect the anonymity of individuals and institutions.

9. Participants have the right to ask questions and have those questions answered. If you have questions about this study, please contact the researcher named above or the researcher's faculty advisor, whose contact information is located at the end of the informed consent. For questions concerning your rights as a research participant, contact Georgia Southern University Institutional Review Board at 912-478-5465.

10. No compensation will be awarded for participation in this project.

11. You understand you do not have to participate in this project and your decision to participate is purely voluntary. If at any time you chose to end your participation in this study, you may do so by telling the primary investigator, Rebekah Roessler. You understand that any current or future care will in no way be affected by participation or refusal to participate in this study.

12. You understand that you may terminate participation in this study at any time with no penalty or prejudice to future care. Owing to the scientific nature of the study, the primary investigator reserves the right to terminate the procedures and/or investigation at any time.

13. You understand there is no deception involved in this project.

14. All information will be treated confidentially. There is one exception to confidentiality that we need to make you aware of. In certain research studies, it is our ethical responsibility to report situations of child or elder abuse, child or elder neglect, or any life-threatening situation to appropriate authorities. However, we are not seeking this type of information in our study nor will you be asked questions about these issues.

15. You must be 18 years of age or older to consent to participate in this research study. If you consent to participate in this research study and to the terms above, please sign your name and indicate the date below.

You will be given a copy of this consent form to keep for your records. This project has been reviewed and approved by the GSU Institutional Review Board under tracking number H19096.

Title of Project: Pain and Acute Musculoskeletal Injury Severity as Predictors of Attentional Capacity

Principal Investigator: Rebekah Roessler, LAT, ATC
Campus Recreation and Intramurals
Post Office Box 8078
Statesboro, GA 30460-8078
Phone: (912) 478-5436
Email: rr04143@georgiasouthern.edu

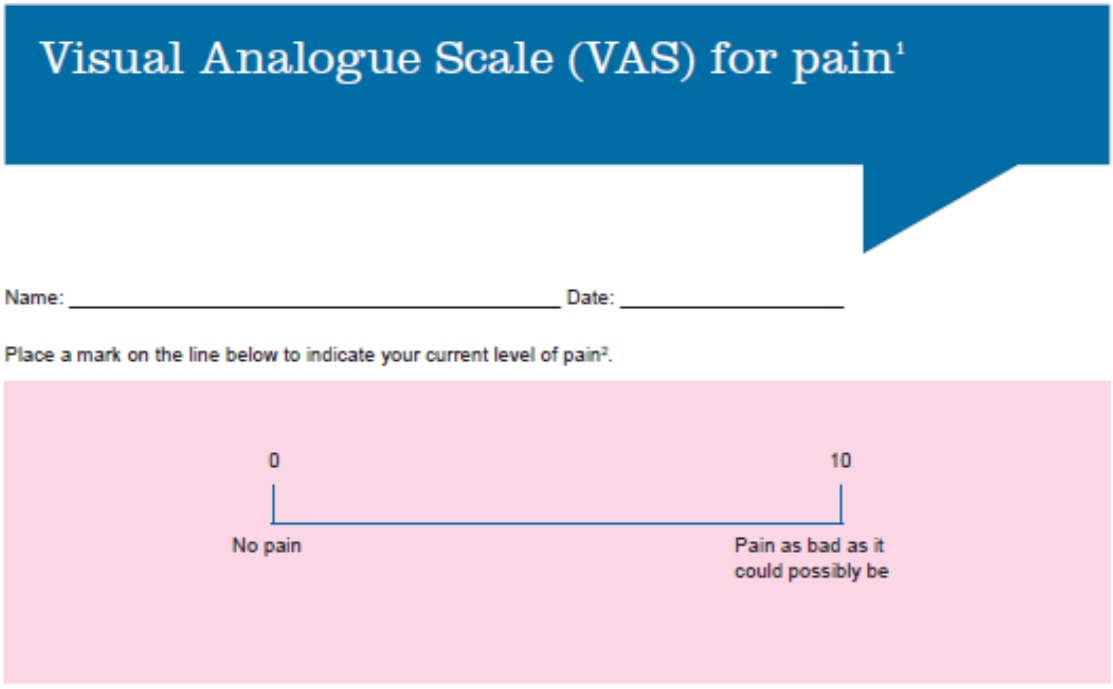
Faculty Advisor: Jessica Mutchler, Ph.D., LAT, ATC, jmutchler@georgiasouthern.edu
Co-Investigators: George Shaver, Psy.D., gwshaver@georgiasouthern.edu
Ronald Snarr, Ph.D., CSCS,*D, EP-C, CPT, rsnarr@georgiasouthern.edu

_____ _____
Participant Signature Date

I, the undersigned, verify that the above informed consent procedure has been followed.

_____ _____
Investigator Signature Date

FIGURE 4: THE VISUAL ANALOG SCALE (VAS)



Visual Analogue Scale (VAS) for pain[1]

Name: _____ Date: _____

Place a mark on the line below to indicate your current level of pain[2].

0 — 10

No pain — Pain as bad as it could possibly be

Please ensure you print this document to scale so that the VAS line is 10cm long.

1 State Insurance Regulatory Authority: *Guidelines for the management of acute whiplash-associated disorders – for health professionals*. Sydney: third edition, 2014. P.43.
2 Scott, J. and E. Huskisson, Graphic representation of pain. Pain, 1976. 2(2): p. 175-184.

sira.nsw.gov.au/acutewhiplash

NSW GOVERNMENT

FIGURE 5: THE TRAIL MAKING TEST A (TMT-A)

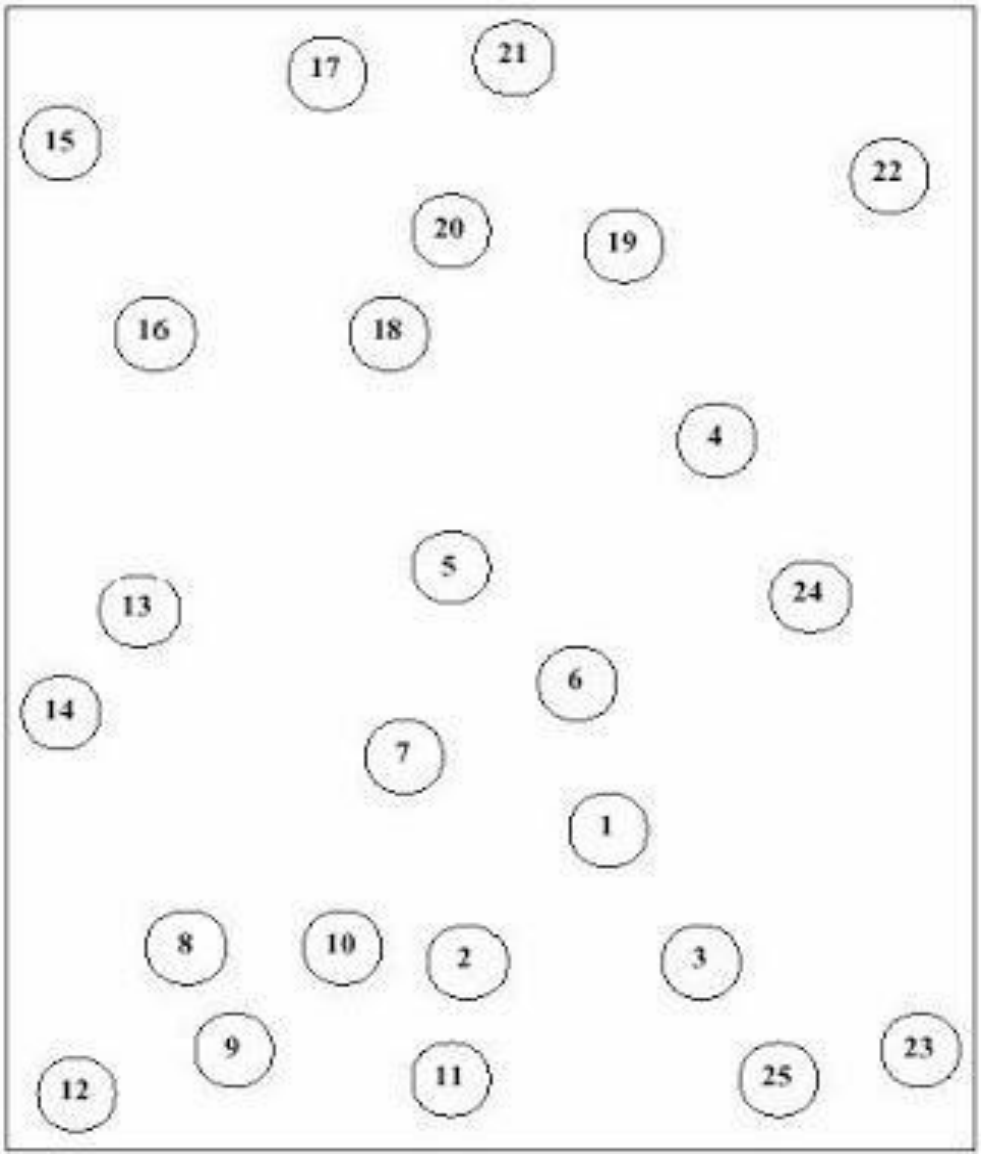


FIGURE 6: THE TRAIL MAKING TEST B (TMT-B)

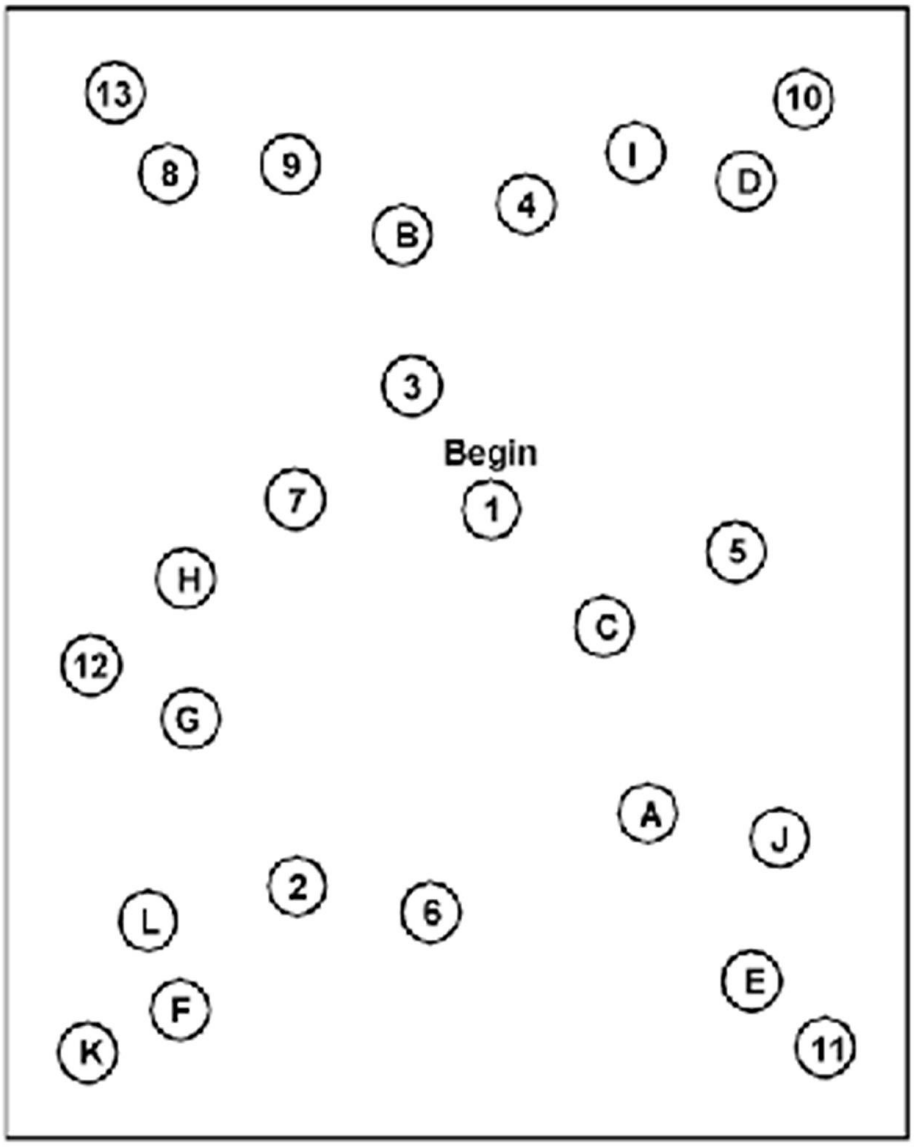
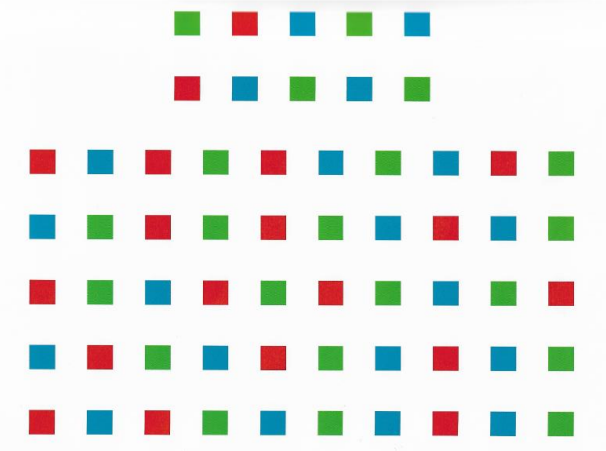
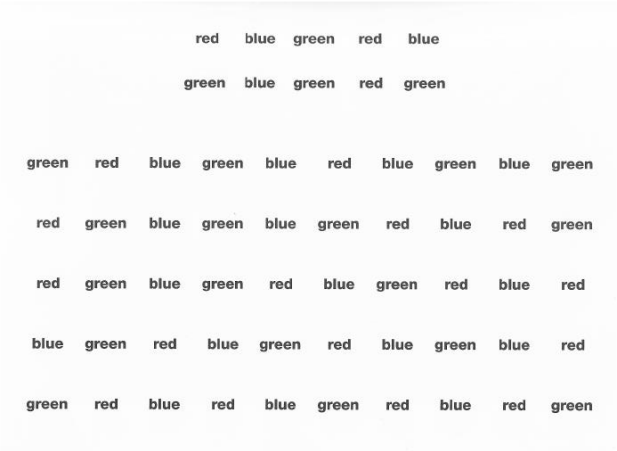


FIGURE 7: THE COLOR-WORD INTERFERENCE TEST (CWIT)

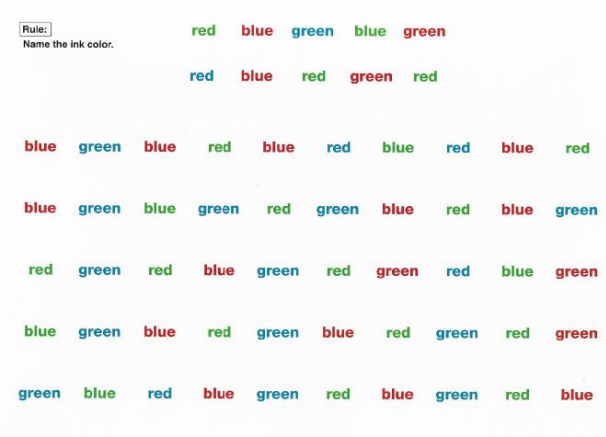
Condition 1:



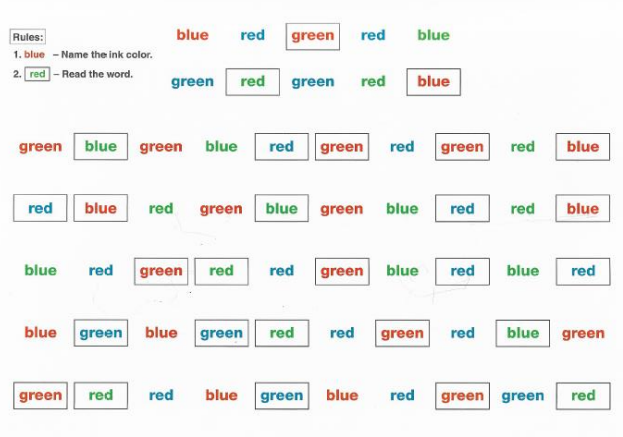
Condition 2:



Condition 3:



Condition 4:



Georgia Southern University
Health Questionnaire

Please answer the following questions as honestly as possible. All answers will remain confidential.

Demographic Information

Name: _____ Date: _____ Time: _____

DOB: _____ Age: _____ Gender: _____ Email: _____

Check current year in school:
___Freshman
___Sophomore
___Junior
___Senior
___5th year
___Master's
___Doctoral
___Other (list highest degree completed: _____)

Is your primary language English? (Circle one) YES NO

Check your ethnicity:
___White
___Black
___Hispanic
___Asian or Pacific Islander
___American Indian or Alaskan
___Other
___Prefer not to say

Please circle the appropriate answer below:

1. Do you currently play a Club Sport? YES NO
   a. If so, what sport? _____
2. Do you currently play intramural sports? YES NO
   a. Is so, what sport? _____
   b. If not, did you previously? Please state when and which sport.

   _____
3. How many hours a week are you physically active for? _____ hours
   (Running, lifting, fitness classes, sports, swimming, etc.)

Brief Health History:

1. Have you ever been:
   - Diagnosed with an attentional disorder? *(ADD, ADHD, etc.)* YES NO
   - Diagnosed with a learning disorder/dyslexia? YES NO
   - Diagnosed with depression, anxiety, or other psychiatric disorder? YES NO
   - Diagnosed with a concussion within the last 6 months? YES NO
2. Are you currently taking any pain medication including Advil/Tylenol?
   a. YES
   b. NO
   c. UNSURE
3. Are you physically sick today? (Cold, flu, allergies, etc.)
   a. YES
   b. NO
   c. UNSURE
4. Are you physically tired from physical activities you participated in today?
   a. YES
   b. NO
   c. UNSURE
5. Have you had any surgeries in the past 6 months? If yes, please list all procedures and when they occurred.
   a. YES: _____
   b. NO
   c. UNSURE
6. Have you had any caffeine today? (Coffee, soda, pre-workout, etc.) If yes, please list how much and what time.
   a. YES: _____
   b. NO
   c. UNSURE
7. Have you ever received neuropsychological or psychoeducational testing? If yes, when and what testing did you do?
   a. YES: _____
   b. NO
   c. UNSURE
8. About how many hours of sleep did you get last night? _____ hours
9. Is there anything else you would like the researchers to know about that may affect this study? (if not, please leave this question blank)

_____

_____

Georgia Southern University
Follow Up Health Questionnaire

Please answer the following questions as honestly as possible. All answers will remain confidential.

Please circle the appropriate answer below:

1. Do you currently play a Club Sport? YES NO
    a. If so, what sport? _____
2. Do you currently play intramural sports? YES NO
    a. Is so, what sport? _____
    b. If not, did you previously? Please state when and which sport.

    _____
3. Are you physically tired from physical activities you participated in today?
    a. YES
    b. NO
    c. UNSURE
4. Are you physically sick today? (Cold, flu, allergies, etc.)
    a. YES
    b. NO
    c. UNSURE
5. Are you currently taking any pain medication including Advil/Tylenol?
    a. YES
    b. NO
    c. UNSURE
6. Have you had any injuries between your initial testing date and now? If yes, please list the injury and date of injury.
    a. YES: _____
    b. NO
    c. UNSURE
7. Have you had caffeine today? (Coffee, soda, pre-workout, etc.) If yes, please list how much and what time.
    a. YES: _____
    b. NO
    c. UNSURE
8. About how many hours of sleep did you get last night? _____ hours

9. Is there anything else you would like the researchers to know about that may affect this study? (if not, please leave this question blank)

_____

_____

_____

APPENDIX D: IRB Letters

Georgia Southern University
Office of Research Services & Sponsored Programs

Institutional Review Board (IRB)

Phone: 912-478-5465 | IRB@GeorgiaSouthern.edu | Veazey Hall 3000, PO Box 8005, Statesboro, GA 30460
Fax: 912-478-0719

To: Roessler, Rebekah; Mutchler, Jessica; Shaver, George; Snarr, Ronald

From: Office of Research Services and Sponsored Programs

Initial Approval Date: 11/5/2018

Expiration Date: 10/31/2019

Subject: Status of Application for Approval to Utilize Human Subjects in Research – **Expedited Review**

After a review of your proposed research project numbered **H19096**, and titled **"Pain and Acute Musculoskeletal Injury Severity as Predictors of Attentional Capacity,"** it appears that (1) the research subjects are at minimal risk, (2) appropriate safeguards are planned, and (3) the research activities involve only procedures which are allowable. You are authorized to enroll up to a maximum of **150** subjects.

Therefore, as authorized in the Federal Policy for the Protection of Human Subjects, I am pleased to notify you that the Institutional Review Board has approved your proposed research.

Description: The purpose of this study is to determine if injury severity and/or perceived pain intensity are predictors of attentional capacity following an acute musculoskeletal injury.

If at the end of this approval period there have been no changes to the research protocol; you may request an extension of the approval period. In the interim, please provide the IRB with any information concerning any significant adverse event, **whether or not it is believed to be related to the study**, within five working days of the event. In addition, if a change or modification of the approved methodology becomes necessary, you must notify the IRB Coordinator **prior** to initiating any such changes or modifications. At that time, an amended application for IRB approval may be submitted. Upon completion of your data collection, you are required to complete a *Research Study Termination* form to notify the IRB Coordinator, so your file may be closed.

Sincerely,

Eleanor Haynes
Compliance Officer

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